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Compressive & Impact-Resisting
Qualities of Bearing Metals

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COMPRESSIVE AND IMPACT-RESISTING QUALITIES OF BEARING METALS

BY

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

ERNEST HARBIN LOUTZENHISER

ENTITLED COMPRESSIVE AND IMPACT-RESISTING QUALITIES OF BEARING METALS

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF Bachelor of Science in Mechanical Engineering

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Instructor in Charge.

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INTRODUCTION

COMPRESSIVE AND IMPACT RESISTING QUALITIES OF BEARING METALS

I. INTRODUCTION

Bearings are surfaces of contact between parts of machine elements having relative motion, whose main function is to guide the motion of these elements. Bearing surfaces are pressed together with considerable force and are also subject to shocks of various degrees of intensity. The chief requirements of a bearing metal are: (1) that it shall be strong enough to resist any stresses that are apt to be put upon it; (2) that it shall have a high melting point and a low coefficient of friction. The use of the less"oily"oils derived from mineral products, now commonly used in all lubrication, calls for a bearing metal of low frictional resistance on account of the oil film being easily broken down, thus leaving the bearing metal exposed to the direct action of the journal. The so-called "white metals" possess these qualities although the brasses and bronzes are still used in heavy work on account of their superior strength. Another advantage of the white metal is the case with which it can be poured into the bearing or taken out and replaced. Its low coefficient of friction makes it possible to use thecheaper oils.

The tests on bearing metals have generally been confined to friction tests, oil tests and tensile tests. Other tests have been made on a small scale by various companies who manufacture

bearing metals. The writer has been unable to find published accounts of impact and compression tests. With a view of determining some of the properties of bearing metals under compression and impact loads, the writer undertook the investigation recorded in this thesis. Compression and impact tests on small cylinders of bearing metal were made on seven varieties of metal. The data of these tests are tabulated and are also shown graphically, the method of testing is described in detail and the significance of the results discussed.

I wish to express my thanks to J.T.Ryerson and Company and to the Merchant and Evans Company who furnished much of the material tested. Also to Mr. Kistinger, the engineer of the American Glyco Company, for his suggestions as to tests.

II. MATERIALS AND TESTS

The kinds of metal tested are listed below and are given test numbers. These metals will hereafter be designated by their test numbers.

No.1- Merchant and Evans' "Special", a medium pried metal for general use containing lead. (donated)

No.2- "Frictionless", a high priced metal for high speed service and light loads, containing lead. (bought in open market)

No.3- "Babbit" No.4. a low priced metal used generally for light and rough work, containing lead. (bought in open market)

No.4- "Marine Glyco", a metal used for marine work, containing lead. (donated)

No.5- "Glyco Metal", for general use- a high priced metal

containing lead. (donated)

No.6- "Genuine" Babbit, composition- Sb 7 1/2 %, Sn 89 %, Cu 3 1/2 %. (made to our special order)

No.7- "Turbo Glyco", a metal for use in turbines, contains lead. (donated)

These metals were made into cylindrical test pieces approximately one and one-half inches in diameter and three inches in length and subjected to tests of impact and compression with the view of obtaining data of a definite character with regard to their impact and compressive resisting qualities. The tests were made in the laboratory of Applied Mechanics of the University of Illinois.

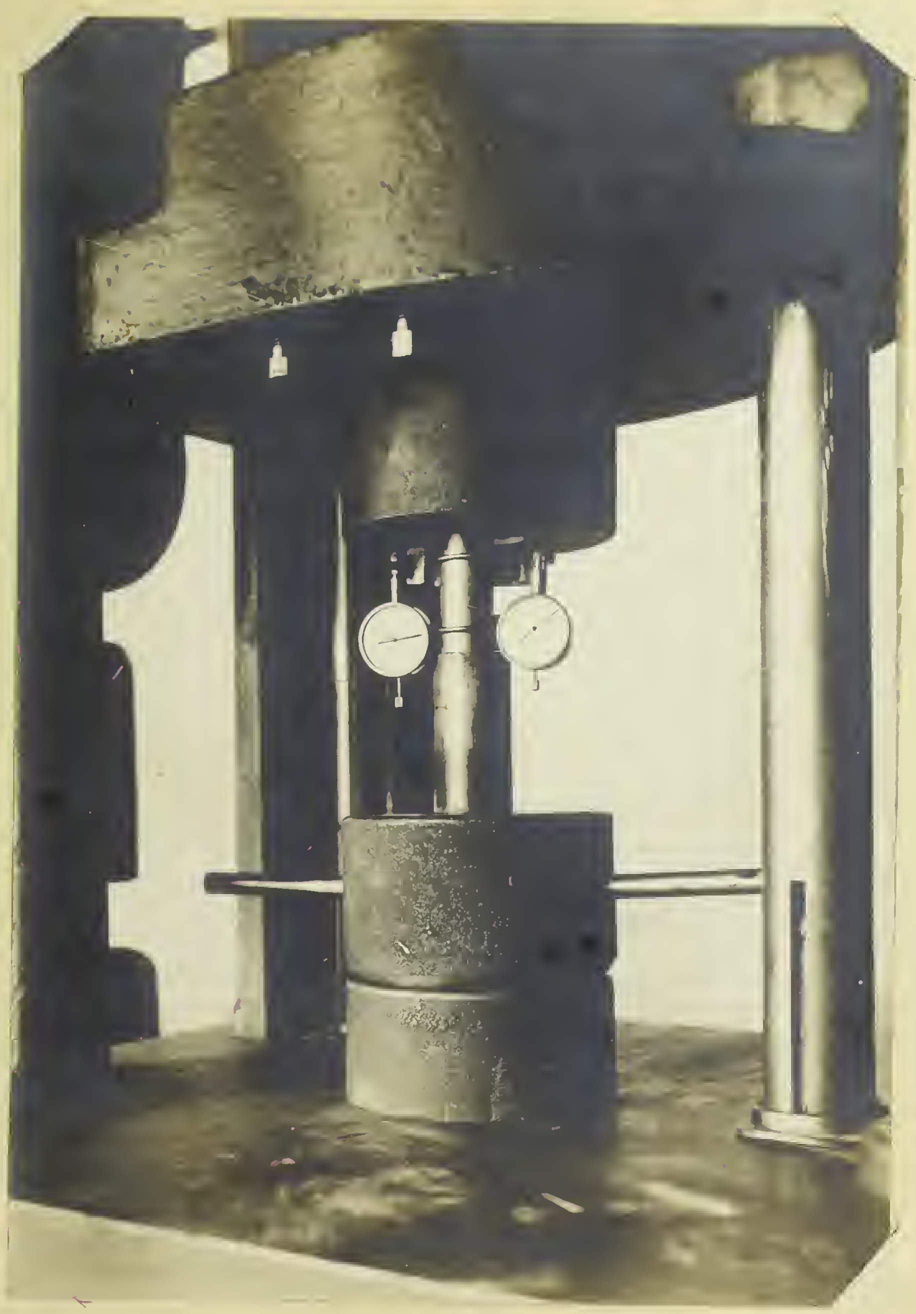
PREPARATION OF THE SPECIMEN: The first step in the preparation of the test specimen is the melting process. Melting was accomplished by heating the metal in a ladle over a forge. Much care was taken not to get the metal too hot, as this causes some of the ingredients to burn, thus changing the composition of the alloy. In some cases this change causes the metal to become very brittle and useless for bearings. There is also danger of pouring the metal while it is too cold. This causes unevenness in the internal structure. The proper temperature is reached when a dry pine stick will just char when stirred in the molten metal. For the casting of these specimens molds were made of moulders' "green" sand. The pattern used was a two-inch shaft. It is important that the molds be free from moisture in order to get sound specimens, as the moisture boils up in the liquid and causes blow-holes. A riser should be provided in order to avoid piping, which is very common in the

casting of bearing metals in this shape. The metal becomes cool enough to take from the molds in from three to five minutes after casting. After the pieces were cooled sufficiently they were taken to the machine shop of the University of Illinois and turned into cylinders three inches in length by one and one-half inches in diameter, though in some cases blowholes necessitated a reduction to one and three-eighths inches in diameter.

The methods of testing were as follows;-

COMPRESSION TESTS,- The specimen was carefully measured with a micrometer and placed as shown in figure 1. The upper and lower parts of the apparatus were fastened to the test pieces by means of steel wire bands placed two inches apart, as measured on the axis of the piece. The extensometers shown were Ames Test Gauges and were fastened by means of three-eighths inch cap-screws to the lower part of the apparatus. The specimen was then mounted as shown, on the table of the Philadelphia 100,000 pound two-screw machine, or on the Olsen 100,000 pound three-screw machine and a compressive load applied. A total initial load of 200 pounds was applied and the extensometers set to read zero. Loads were then applied by increments of 1000 or 2000 pounds until a limit was reached either in the endurance of the material or in the capacity of the machine. Another method of compressive test was the time test, in which the piece was subjected to a total load of 4000 pounds and kept under this load for a period of five minutes, the extensometers having been read at the beginning and end of this time. The machine speed was one fiftieth of an inch per minute.

FIGURE 1



APPARATUS USED IN COMPRESSION TESTS

IMPACT TESTS,- The impact machine consisted essentially of a weight, W, figure 2, attached to an arm, A, guided by means of uprights, U, in such a manner as to fall, when released, upon the anvil, B, which weighed approximately ten times the weight of the hammer. This hammer, which is the arm and weight taken together, turned on a pin as shown at the right of the photograph. It weighed at first 47.5 pounds, but was increased to 49.48 pounds while testing metal No.3, on account of the breaking of the arm from the weight. During the testing of the fifth kind of metal the weight was changed to 49 pounds for a similar reason. A graduated arc, G, was fastened to the arm and was marked to read, in inches, the height of rise of the center of gravity of the hammer. The test piece was placed upon the anvil so as to be struck by the center of percussion of the moving parts, which was determined by experiment. The hammer was then lifted to a given height by means of a small tackle and suddenly released by a trigger. Some of the pieces were measured after each blow, others after several blows had been given. Before testing in impact, each piece was measured with micrometers, then a line was marked on the piece parallel to the axis. On this line were laid off distances of one inch above and below the midpoint of the axis. These divisions were measured after each trial and recorded as shown in the sample notes, page 21.

OBSERVATIONS: The methods of taking data may best be explained by reference to the "Sample Field Notes" given on page The left hand side of the page contains data of a compression test. The total load given in the first column was read from the scale beam. The second column is the calculated load per

FIGURE 2

IMPACT MACHINE

square inch of section area of the test piece. The remaining columns of the compression test give the compression of the piece at each load, as read from the extensometers. left and right refer to the readings of the left and right gages as shown in the photograph. The last two columns give the mean reading of these two extensometers and the calculated compression per inch length of the specimen on the basis of these mean values.

On the right hand side of the page is a sample of the impact data. The "fall in inches" in the first column refers to the fall of the center of gravity of the hammer as read from the graduated arc. The next two columns under "Gage lengths" give the lengths of the upper and lower inch-marks described above. The fourth column gives the number of blows the piece has received before the reading is taken. In the last column is recorded the energy expended upon the piece between two readings. This energy is given in inch-pounds per cubic inch volume of the test piece.

III. EXPERIMENTAL DATA AND DISCUSSION.

METHODS OF CALCULATION: In the compression tests calculations were made of the load per square inch of section area, which was found by dividing the total load by the cross--sectional area of the test piece, and of the mean compression per inch of length, which was found by dividing the mean compression in the two-inch gage distance by two. In the impact calculations the energy per cubic inch was found by taking the product of the weight of the hammer into the distance, in inches, of the fall of the center of gravity and dividing the product by the cubic

contents of the test piece. In case several blows had been given from the same height before the reading, this quantity was multiplied into the number of blows.

The establishment of the elastic limit was by the Johnson method. This limit is known as the"apparent elastic limit" and is found as follows; a tangent line is drawn to the stress diagram at the origin, from which a line making with the load line an angle whose tangent is fifty per cent greater than that of the first tangent line is drawn. A line is then drawn parallel to this latter line and tangent to the load curve. The point of tangency represents the apparent elastic limit of the material.

RESULTS: The immediate results of these tests are given on pages 22, 23, and 24. On page 22, are the results of the compressive tests; for each kind of metal is given the load, in pounds per square inch, and the compression, in ten-thousandths of an inch per inch length, produced by the load. The sample numbers refer to the different kinds of metal tested; sample No.6 is "Genuine" Babbit. In the impact tests the results given are the energy of impact per unit volume as explained above, and the upper and lower gage lengths. The upper number under "D", corresponding to the energy of impact on the left, represents the the length of the upper gage mark; the number below this represents the length of the lower mark. The upper face of the test piece was struck by the hammer while the lower face rested on the anvil. On page 24 are the results of the constant load tests and also of the repeated blow tests.

On page 13 to 20 inclusive are curves of the impact tests, and on page 12 are curves of the compression tests.

The compression curves are platted with the load in pounds per square inch as ordinates and with compression in inches per inch length as abscissa. The impact curves show the relation between the energy of impact in inch pounds per cubic inch, as ordinates, and permanent set, in inches per inch, as abscissa. The two curves show the relation between the deformation of the lower and upper parts of the test piece. The energy of impact shown on these curves is the total impact that has been expended upon the piece since the beginning of the test until the reading is taken. The impact curves are taken as the mean of the two sets of data given on page 23 and 24 .

The summarized results of these tests are given in the following tables, the materials are listed in the order of their respective qualities:

TABLE NUMBER 1

COMPARISON OF STRENGTH (elastic limit in pounds per square inch)

No.1	No.4	No.6	No.7	No.5	No.2	No.3
6000	6000	4000	3000	3000	2200	2000

TABLE NUMBER 2

IMPACT TRANSMITTING QUALITIES (ratio of permanent set in lower part to that in upper part)

No.4	No.5	No.3	No.7	No.1	No.6	No.2
1.00	0.905	0.833	0.827	0.704	0.578	0.485

These values represent the mean of each test.

TABLE NUMBER 3

IMPACT RESISTING QUALITIES (permanent set under impact)

No.6	No.1	No.7	No.5	No.4	No.2	No.3
.068	.106	.112	.124	.127	.144	.171

These values are found from the curves of total deformation given on page 20. They represent the total permanent set in inches for the total impact which is given in inch pounds per cubic inch of the test piece. (2000 inch pounds per cubic inch)

DISCUSSION OF RESULTS AND CONCLUSIONS: The load curves on page 12, show that there is quite a difference in the resisting qualities under compression. In these curves the line passes through most of the points taken, giving a very smooth curve. The curve of metal number 1 is a mean of two tests made on different pieces of the same kind of metal. The results of these two tests coincided very closely. Of all metals tested No.1 had the highest resistance against failure. It was tested to 14900 pounds per square inch. It had also the highest elastic limit but No.4 showed as high value. No.3 had the lowest elastic limit. "Genuine" Babbit is found to have an elastic limit of 4000 pounds per square inch, as shown under No.6. No.4 and No.5 are stronger than this; the other samples,however, show lower values. In the constant load test, No.1 also shows the greatest resistance, after it are No.7, No.5 and No.6 in order. No.3 shows the lowest resistance in this test also, having a far greater compression than any others. The effects of impact and compression on pieces tested to excess are shown in the photograph (page 9) figure 3. On the right are the failures due

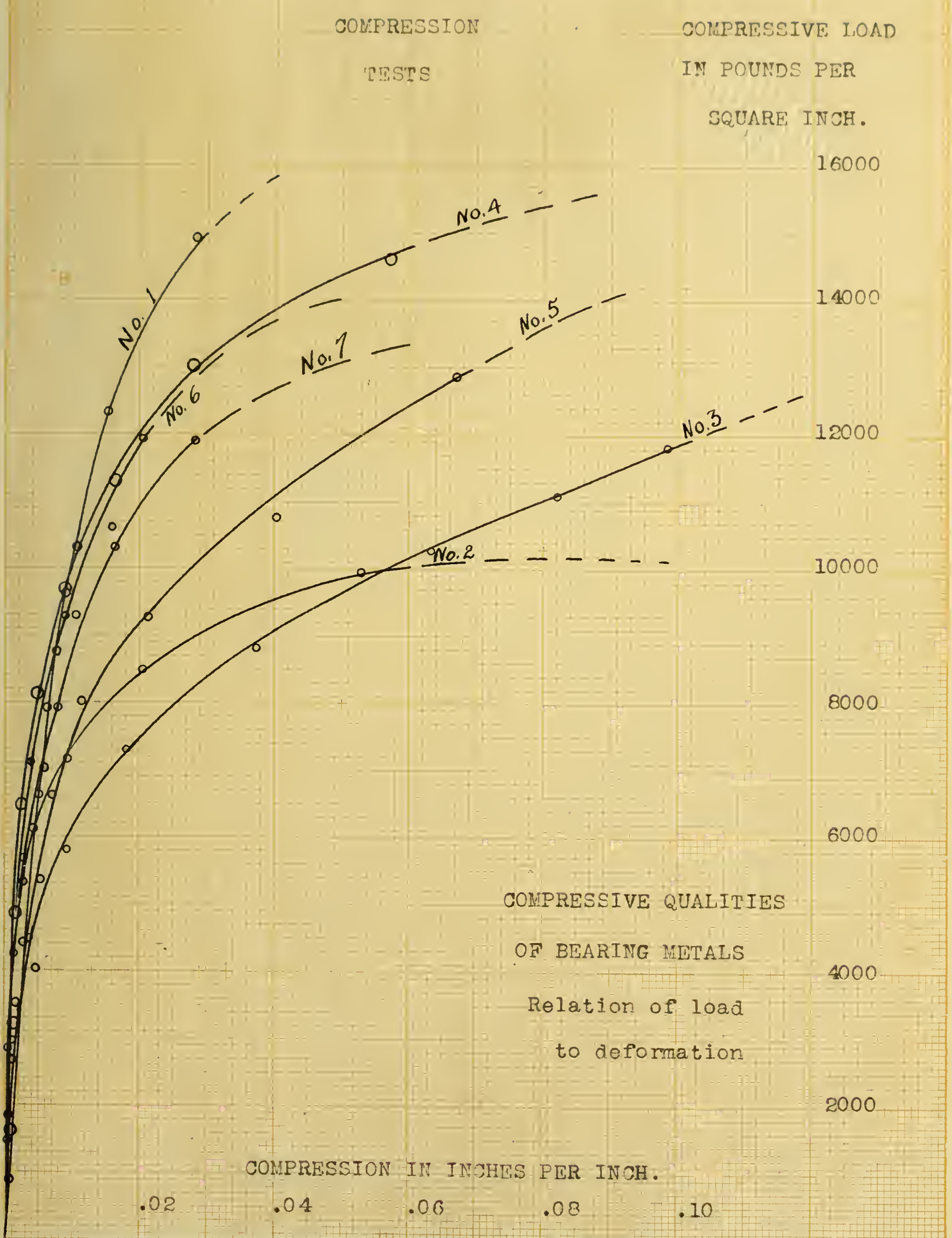
to compression and on the left those due to impact.

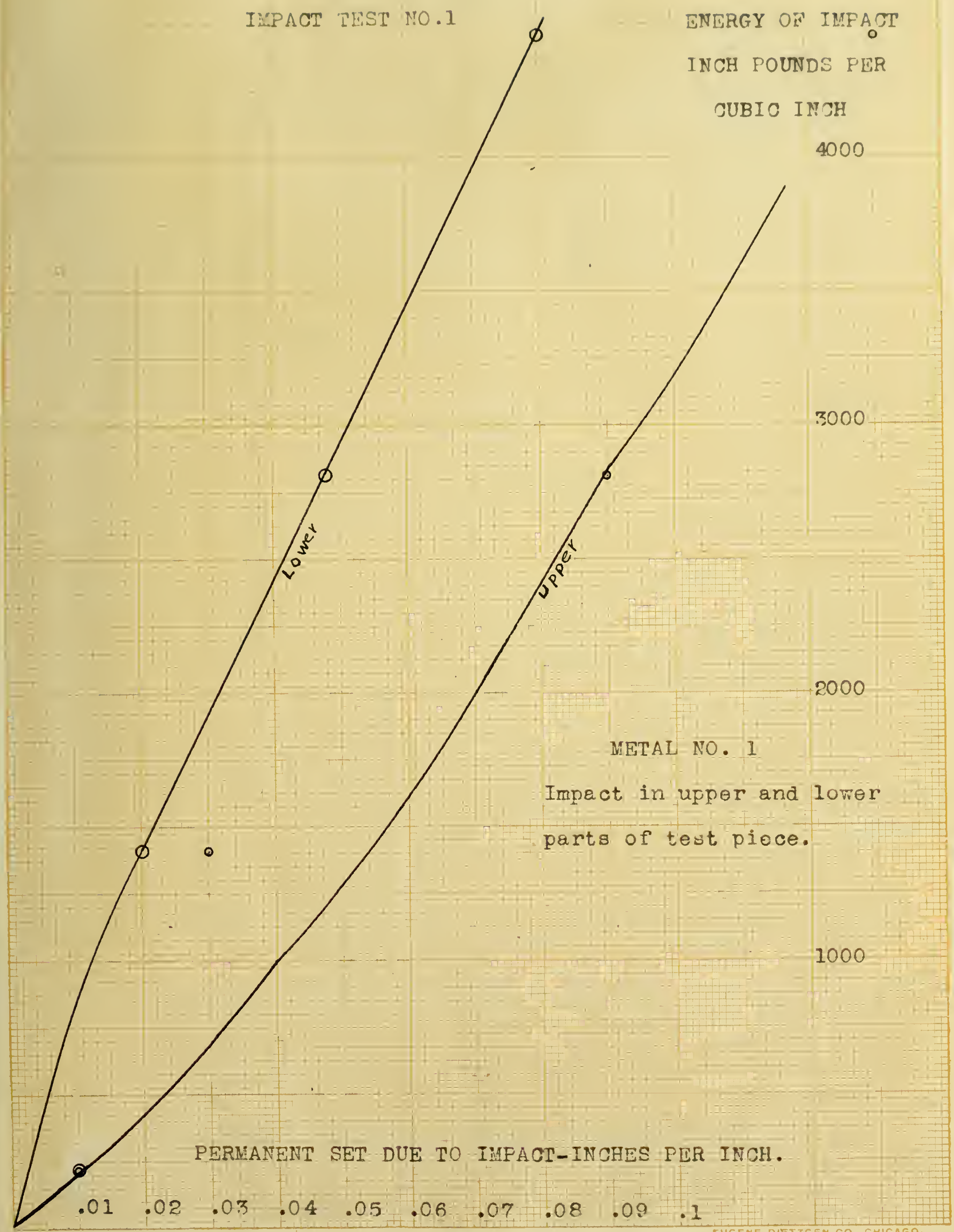
The impact tests show that there is more or less difference in the transmitting qualities of the different metals; i.e., in the ratio of the deformation of the lower part to that of the upper part. No.4 has the average value of unity, No.5 and No.3 come next. No.3 shows a high value in this respect as compared with the low values it has in other respects. No.6, which stands among the higher values in other respects, shows a rather low ratio of transmission.

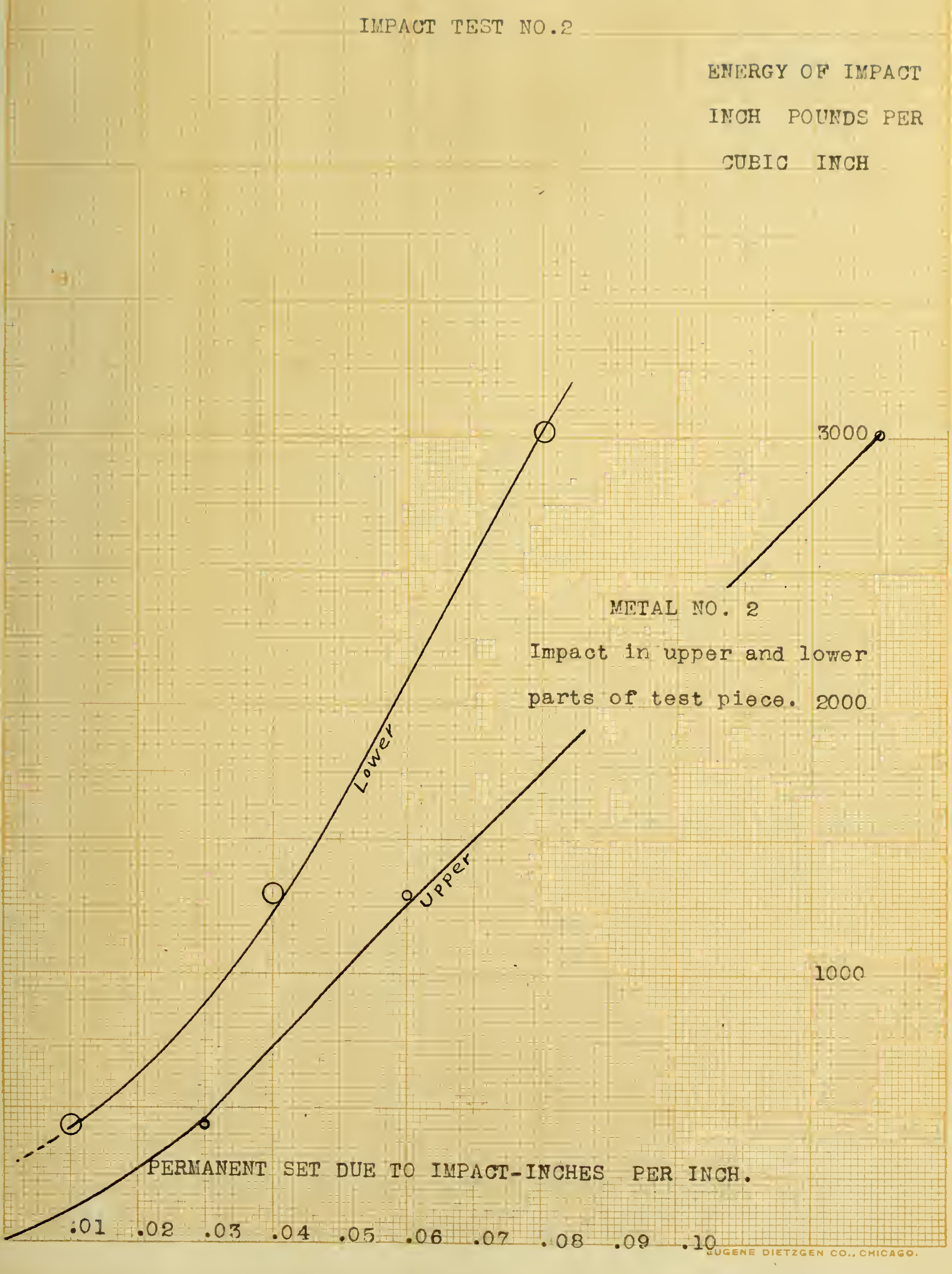
These tests seem to indicate that No.1, No.4, and No.6 are better adapted for use under higher pressures, while the others may be used for lower pressures. No.3 should be used only for light work or for work in which it is not oecessary for the bearing to keep its shape perfectly. The impact tests given here show that these metals could not be used under a very heavy shock. The metals Nos.1,4, and 6 could be used under pressures of about 3000 pounds per square inch, while the others could be used under much lower pressures.

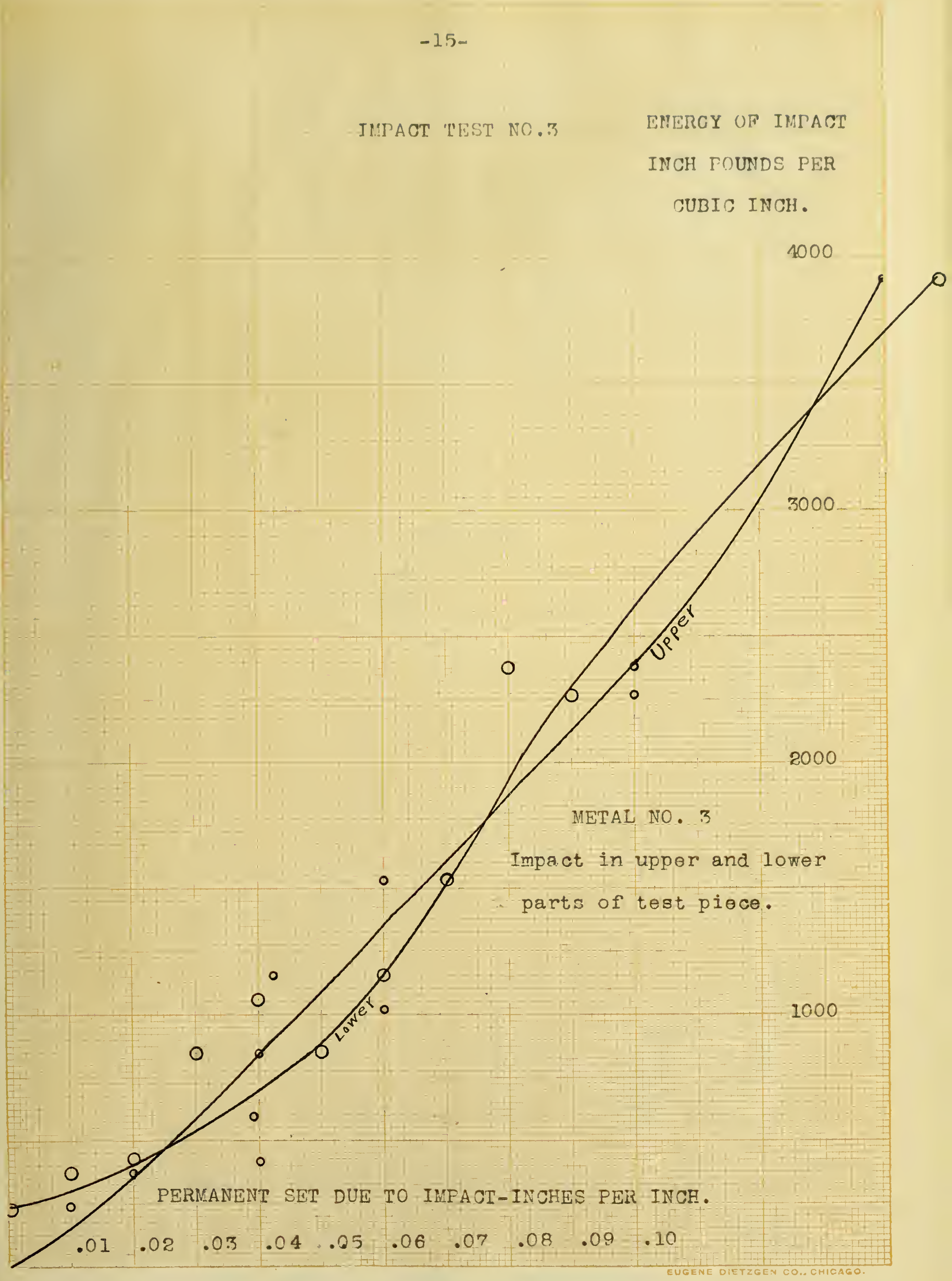
Bearings are subjected to other destructive influences as well as to impact and compression, and doubtless other methods ot testing would show other valuable properties of the metals. One of the very important influences acting on bearings is wear. Granted that the bearing is made strong enough to resist the compressive and dynamic stresses, the thing the purchaser of a bearing metal will ask is, "how long will it last"? This could be determined by wearing tests and the values found would be of high commercial importance. A good method for making compressive tests is by testing the metal in the shape of an actual

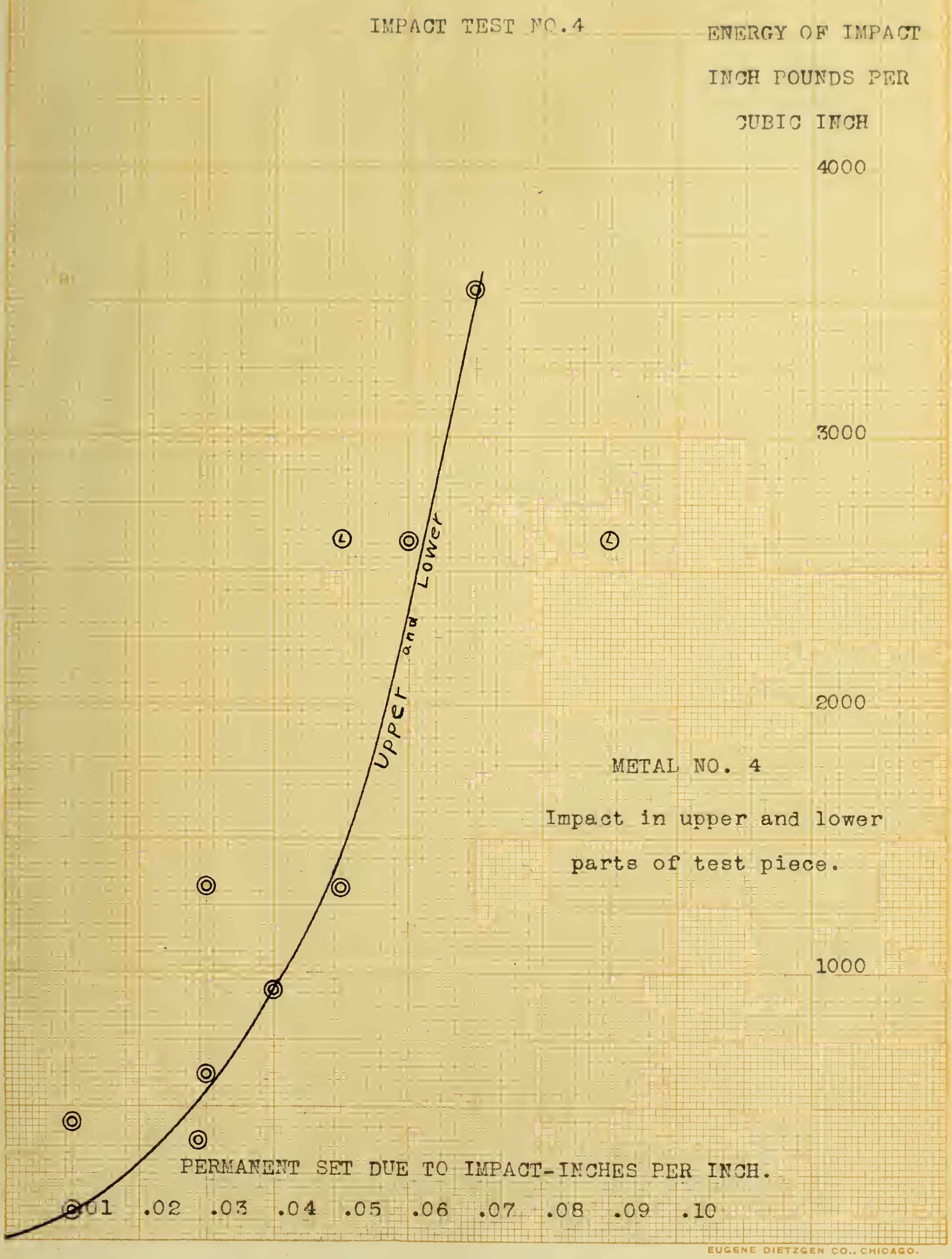
bearing. In this test, however, it is necessary to make very small measurements of the deformation. In the only tests made on pieces of this shape it was found that the metal gave higher resistance to compression than it did in the cylindrical form. The elastic limit should be determined per square inch of projected area in order that the proper size of bearing for any particular kind of bearing metal could be easily determined. Another very valuable test as to the relative qualities of the metals could be determined by means of actual working tests, the metal being put into actual bearings and the amount of wear and permanent deformation measured from time to time.

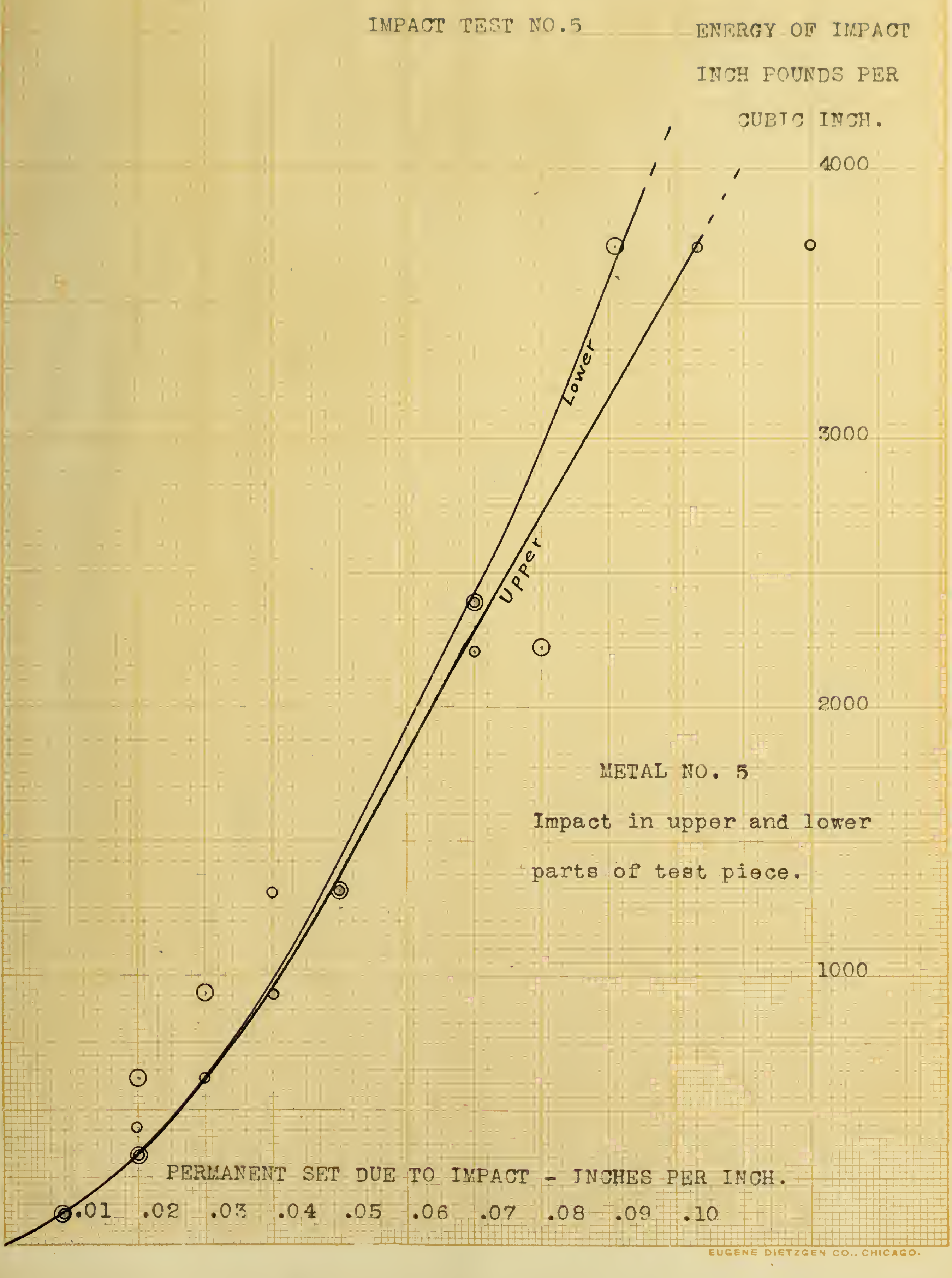

COMPRESSION
TESTS
COMPRESSIVE LOAD
IN POUNDS PER
SQUARE INCH.
16000
14000
12000
10000
8000
6000
4000
2000
No. 1
No. 4
No. 6
No. 7
No. 5
No. 3
No. 2
COMPRESSIVE QUALITIES
OF BEARING METALS
Relation of load
to deformation
COMPRESSION IN INCHES PER INCH.
.02
.04
.06
.08
.10

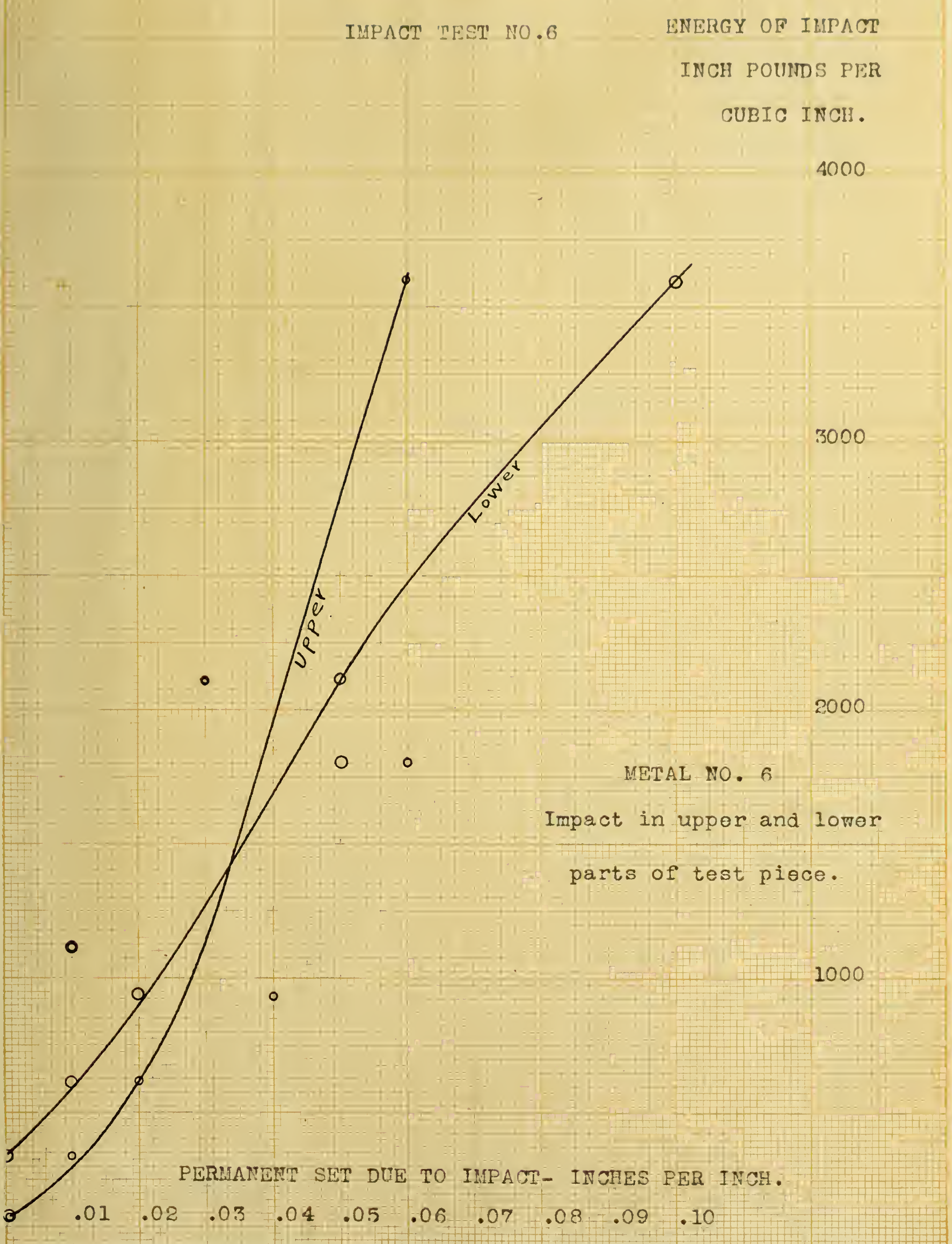

IMPACT TEST NO.1
ENERGY OF IMPACT
INCH POUNDS PER
CUBIC INCH
4000
3000
2000
1000
Lower
Upper
METAL NO. 1
Impact in upper and lower
parts of test piece.
PERMANENT SET DUE TO IMPACT-INCHES PER INCH.
.01
.02
.03
.04
.05
.06
.07
.08
.09
.1

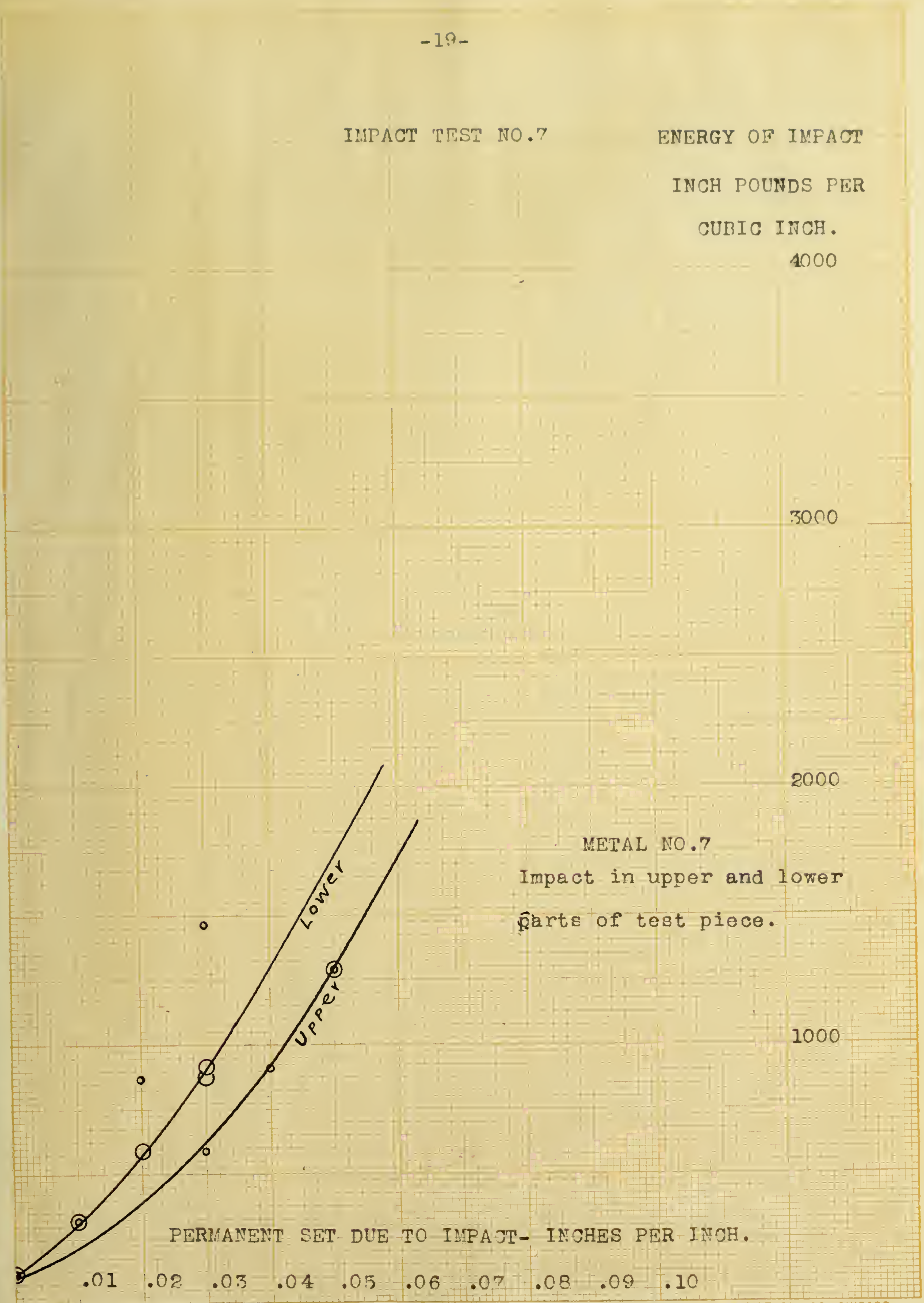

IMPACT TEST NO.2
ENERGY OF IMPACT
INCH POUNDS PER
CUBIC INCH
3000
METAL NO. 2
Impact in upper and lower
parts of test piece.
2000
Lower
Upper
1000
PERMANENT SET DUE TO IMPACT-INCHES PER INCH.
.01
.02
.03
.04
.05
.06
.07
.08
.09
.10
EUGENE DIETZGEN CO., CHICAGO.

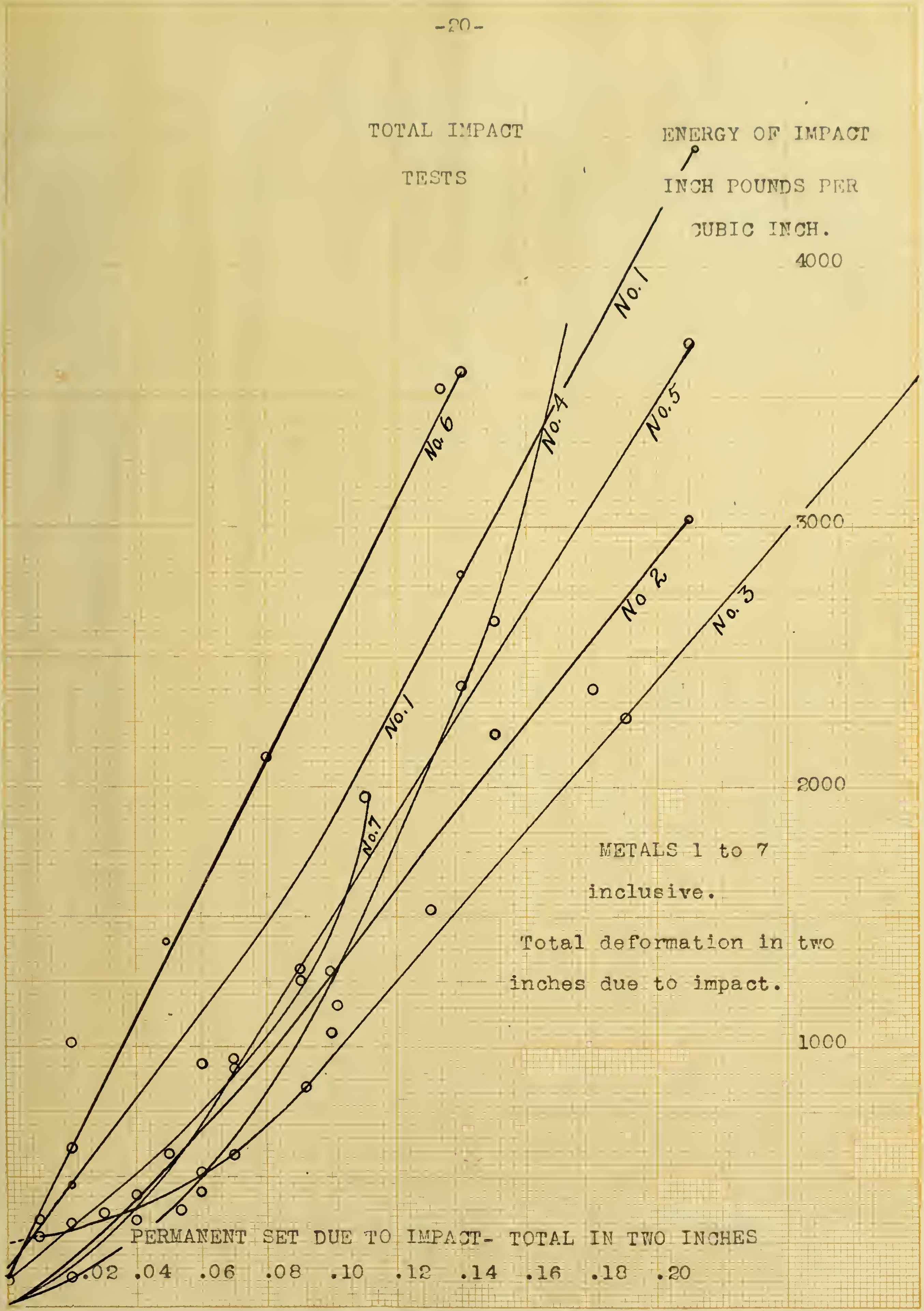

IMPACT TEST NO.3
ENERGY OF IMPACT
INCH POUNDS PER
CUBIC INCH.
4000
3000
2000
1000
Upper
Lower
METAL NO. 3
Impact in upper and lower
parts of test piece.
PERMANENT SET DUE TO IMPACT-INCHES PER INCH.
.01
.02
.03
.04
.05
.06
.07
.08
.09
.10
EUGENE DIETZGEN CO., CHICAGO.


IMPACT TEST NO.4
ENERGY OF IMPACT
INCH POUNDS PER
CUBIC INCH
4000
3000
2000
1000
Upper and Lower
METAL NO. 4
Impact in upper and lower
parts of test piece.
PERMANENT SET DUE TO IMPACT-INCHES PER INCH.
.01
.02
.03
.04
.05
.06
.07
.08
.09
.10
EUGENE DIETZGEN CO., CHICAGO.


IMPACT TEST NO.5
ENERGY OF IMPACT
INCH POUNDS PER
CUBIC INCH.
4000
3000
2000
1000
Lower
Upper
METAL NO. 5
Impact in upper and lower
parts of test piece.
PERMANENT SET DUE TO IMPACT - INCHES PER INCH.
.01
.02
.03
.04
.05
.06
.07
.08
.09
.10


IMPACT TEST NO.6
ENERGY OF IMPACT
INCH POUNDS PER
CUBIC INCH.
4000
3000
2000
1000
Upper
Lower
METAL NO. 6
Impact in upper and lower
parts of test piece.
PERMANENT SET DUE TO IMPACT- INCHES PER INCH.
.01
.02
.03
.04
.05
.06
.07
.08
.09
.10


IMPACT TEST NO.7
ENERGY OF IMPACT
INCH POUNDS PER
CUBIC INCH.
4000
3000
2000
1000
METAL NO.7
Impact in upper and lower
parts of test piece.
Lower
Upper
PERMANENT SET DUE TO IMPACT- INCHES PER INCH.
.01
.02
.03
.04
.05
.06
.07
.08
.09
.10


TOTAL IMPACT
TESTS
ENERGY OF IMPACT
INCH POUNDS PER
CUBIC INCH.
4000
3000
2000
1000
No. 1
No. 6
No. 4
No. 5
No. 1
No 2
No. 3
No. 7
METALS 1 to 7
inclusive.
Total deformation in two
inches due to impact.
PERMANENT SET DUE TO IMPACT- TOTAL IN TWO INCHES
.02 .04 .06 .08 .10 .12 .14 .16 .18 .20

SAMPLE OF FIELD DATA

Sample No. 3A (compression)							Sample No. 3A' (impact)				
Load		Compression (in .0001 inch)					Fall in	Gage Length		Blows	Energy
Total	Lbs per Sq In	Left	Right	Mean	Per inch		inches	Upper	Lower		per Cu. In.
200	147	0	0								
2000	1470	16	0	8.0	4.00		0	1	1	0	
4000	2950	25	26	25.5	12.75		10	.99	1-	2	210
6000	4420	33	70	61.5	30.75		15	.98	.99	1	158
8000	5880	155	145	150.0	75.00		20	.96+	.97	1	211
10000	7350	400	327	363.5	181.75		25	.96	.95	1	264
12000	8840	860	643	751.5	375.75		30	.96-	.94	1	312
14000	10300	1460	1082	1271.0	635.50		35	.94	.93	1	370
15000	11050	1845	1445	1645.0	822.50		35	.90	.91	2	740
16000	11800	2125	1810	1967.5	983.75		Dia. 1.3779", L 3.1050, Vol. 4.5 Cu. In.				
200	147	2086	1731	1908.5			Energy is in inch-pounds.				
Dia. 1.3225" Area 1.36 Sq. In., L 3", G. 2"											

RESULTS OF COMPRESSION TESTS

Sample 1		Sample 2		Sample 3		Sample 4		Sample 5		Sample 6		Sample 7	
Load	Comp.	Load	Compres.	Load	Comp.	Load	Comp.	Load	Comp	Load	Comp	Load	Comp
880	3.0	1420	2.75	1470	4.00	1620	3.50	1340	5.00	1540	2.75	1330	4.50
1750	7.5	2830	5.75	2950	12.75	3240	13.75	2680	18.75	3180	8.75	2700	10.75
2640	13.5	4250	11.50	4420	30.75	4850	18.25	4030	35.00	4920	20.00	3980	21.00
3500	20.0	5690	30.25	5880	75.00	6480	25.75	5350	45.25	5800	31.75	5300	34.75
4400	28.5	7100	93.75	7350	181.75	8100	46.25	6700	62.50	7190	45.00	6650	51.00
5250	36.0	8500	202.25	8840	375.75	9700	85.00	8050	110.75	7950	63.25	7900	71.75
6150	45.0	9900	529.50	10300	635.50	11320	164.75	9380	213.75	9300	97.25	9300	102.75
7900	64.5			11050	822.50	13000	276.75	10750	406.00	10600	167.50	10340	166.75
8780	75.0			11800	983.75	14600	573.75	12900	668.75	11900	209.25	11950	287.75
9660	87.5												
10300	107.5												
12300	151.0												
14900	287.5												

Note:- Load is given in pounds per square inch. Compression is in ten-thousandths inches per inch length of piece.

RESULTS OF IMPACT TESTS

No. 1 E	No. 1 D	No. 2 E	No. 2 D	No. 3 E	No. 3 D	No. 4 E	No. 4 D	No. 5 E	No. 5 D	No. 6 E	No. 6 D	No. 7 E	No. 7 D
470	.01 .01-	432	.03 .01	210	.01 .00	109	.01- .01-	110	.01- .01-	109	.00 .00	107	.00 .00
930	.03 .02	864	.06 .04	158	.02 .01	220	.03- .03-	220	.02- .02-	218	.01 .00	214	.01 .01
1412	.09 .05	1728	.13 .08	211	.04- .03	275	.03 .03	275	.03 .02	274	.02 .01	268	.03 .02
1640	.13 .08			264	.04 .05	329	.04 .04	330	.04 .03	329	.04 .02	321	.04 .03
				312	.04+ .06	385	.05 .05	385	.05 .05	875	.06 .05	386	.05 .05
				370	.06 .07	1320	.06 .09	880	.07 .08				
				740	.10 .09								

E is energy of impact in inch-pounds per Cu. In

D is permant set in upper and lower gage marks

COMPRESSION-RESULTS OF CONSTANT LOAD TESTS

No. 1		No. 2		No. 3		No. 4		No. 5		No. 6		No. 7	
Lbs. pr. In.	Def.	L	D	L	D	L	D	L	D	L	D	L	D
3150	.25	3250	1.5	2680	20.75	2694	1.25	3250	.75	2580	.85	2660	.50

IMPACT TESTS - RESULTS OF REPEATED BLOWS

No. 1		No. 2		No. 3		No. 4		No. 5		No. 6		No. 7	
Energy	Gage	E	G	E	G	E	G	E	G	E	G	E	G
See page 23		See page 23		424	.96 .98	440	.99 .99	435.2	.98 .98	124	1.00 1.00	870	.98 .97
				634	.94 .96	880	.97 .97	870.4	.96 .95	992	.99 .99	1090	.97 .92
				1320	.90 .92	1320	.94 .95	1090.	.93 93	992	.97 .95		
				1540	.86 .85	880	.93 .93	1310	.88 .91	1490	.94 .90		

Note:- Energy is in inch-pounds per Cu. In. Gage length in inches is given for upper and lower parts of piece in order.